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NATIONAL BUREAU OF STANDARDS *January 1966*

Technical News Bulletin

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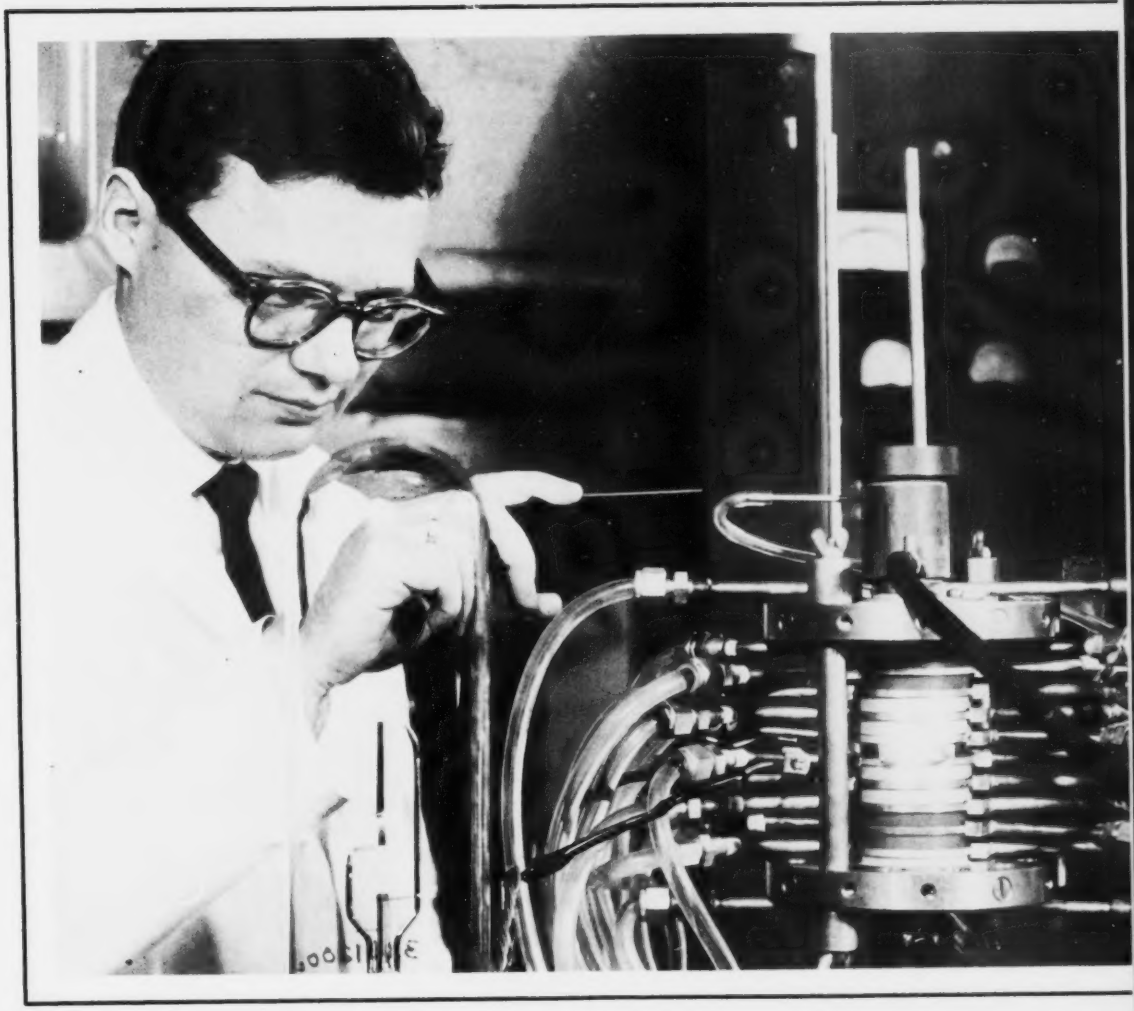

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

Technical News Bulletin

JANUARY 1966/VOL. 50, NO. 1/ISSUED MONTHLY

U.S. DEPARTMENT OF COMMERCE
John T. Connor, Secretary

NATIONAL BUREAU OF STANDARDS
A. V. Astin, Director

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COVER

W. L. Wiese observes a high-temperature plasma through a piece of filter glass. The Bureau has designed and built an electronic data processing system to study the light emitted from such high temperature sources.

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The National Bureau of Standards serves as a focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. For this purpose, the Bureau is organized into three institutes—
• The Institute for Basic Standards
• The Institute for Materials Research
• The Institute for Applied Technology
The TECHNICAL NEWS BULLETIN is published to keep science and industry informed regarding the technical programs, accomplishments, and activities of all three institutes.

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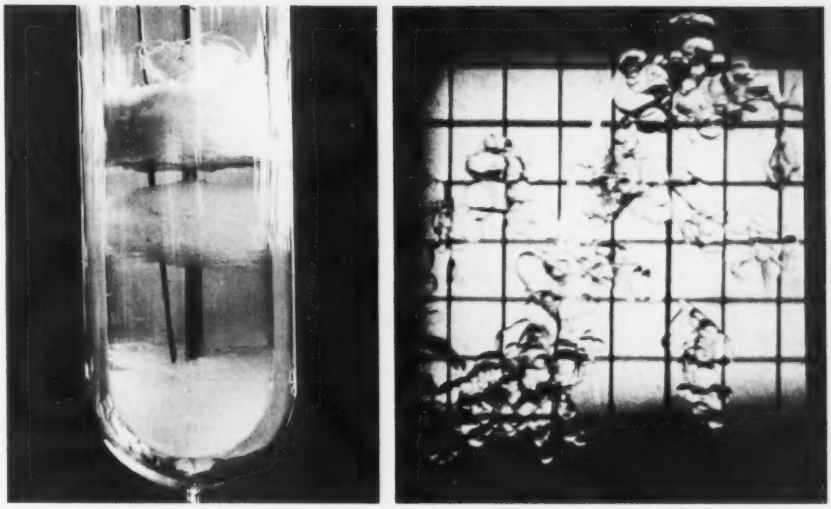


Left: *Slush hydrogen is formed at the bottom of a flask. Solid hydrogen, formed on the surface of liquid hydrogen, sinks to the bottom, and breaks into very fine particles. This combination of liquid and very fine, solid particles of hydrogen—slush hydrogen—is the desired form of hydrogen for rocket fuels. Right: Solid hydrogen particles tumbling through liquid hydrogen, as shown by a high-speed camera. The particles are photographed in exact relation to a 2-mm grid spacing.*

SLUSH HYDROGEN

being studied

■ The characteristics of a mixture of solid and liquid hydrogen, called slush hydrogen, are being investigated at the cryogenics laboratory of the NBS Institute for Materials Research in Boulder, Colo. Under the sponsorship of the National Aeronautics and Space Administration, NBS staff members D. B. Mann and D. B. Chelton and their associates have developed a laboratory method of producing slush hydrogen, a material that may have potential as an advanced rocket fuel. The method involves a freeze-thaw process, which could be used to manufacture large quantities of slush hydrogen in batch-type slush generators or in large hydrogen storage dewars.

As a fuel for sophisticated rocket engines such as the Saturn and Centaur, slush hydrogen would have two advantages over the presently used liquid hydrogen. First, slush hydrogen requires less storage space because of its greater density. Secondly, it has a considerably longer storage time which would be valuable on long space flights.

In the newly developed process, solid hydrogen is formed on the surface of liquid hydrogen by vacuum pumping. Then, after careful pressure modulation, the solid, porous mass breaks loose from the container walls, sinks to the bottom of the tank, and breaks into very fine particles. These very fine, solid particles in liquid make up the desired form of slush hydrogen.

Experimental and analytical interest are centered primarily on the shape and distribution of the solid hydrogen particles, and the effects of aging upon them. In addition, it is believed that the theory of slurry flow, developed for pipeline transport of crushed ore or coal in water, could be applied to the case of hydrogen slush. Therefore, data on particle size and terminal velocity of the particles as they settle in the liquid are being accumulated and analyzed with the aid of high-speed photography and a computer.

Present and future studies of the properties and characteristics of slush hydrogen by NBS scientists should lead to a more complete understanding of the potential of slush hydrogen as an upgraded rocket fuel, thus aiding the Nation's space effort.

Improved method for standardizing

FLUORESCENT LAMP COLORS

■ An improved method for standardizing fluorescent lamp colors was recently developed by Harry K. Hammond III, Marshall J. McDonald, and Dale R. Charlton of the NBS Institute for Basic Standards. In this method, a spectroradiometer is employed to determine the chromaticities—that is, the quality of the colors—of fluorescent lamps.

The instrument has been used to recalibrate the fluorescent lamps maintained at NBS as color standards. The values thus found for the chromaticity coordinates (x and y) which define the colors of the lamps did not differ markedly from those previously derived with a visual calibration method; however, the new values were reproducible to a higher degree of precision than could be achieved visually.

The spectroradiometric technique has additional advantages: it provides a sound physical—rather than visual—basis of measurement; it eliminates variables caused by human observers; it provides relative spectral irradiance data for calculating the color rendition of objects illuminated by the lamps; and it is readily adapted to the calibration of new lamps containing varied phosphor combinations.

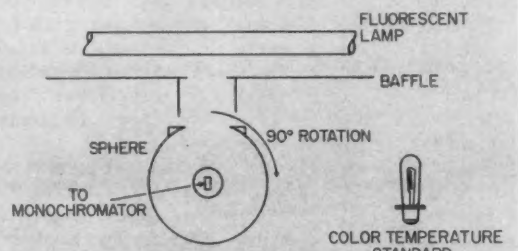
Spectroradiometric measurements generally require: (1) an element for collecting and uniformly mixing the light to be measured; (2) an element for dispersing the radiant flux from the light source under test into its spectral constituents; (3) a detector for converting the radiant flux to an electric current; (4) a readout device for indicating the detector current; and (5) a standard light source of known spectral irradiance. From such an assembly, the relative spectral irradiance data may be derived and the chromaticity coordinates of a fluorescent lamp may be determined.

In the instrument constructed at NBS, a sphere, 20 cm in diameter, coated with barium sulfate, and having a 7.6-cm aperture, is the collecting element; a double-grating monochromator is the dispersing element. The entrance and exit slits of the monochromator are equal and are set to pass a spectral band of 5.6 nanometers (nm). The detector is an S-20 multiplier-type phototube with high sensitivity throughout the visible spectrum.

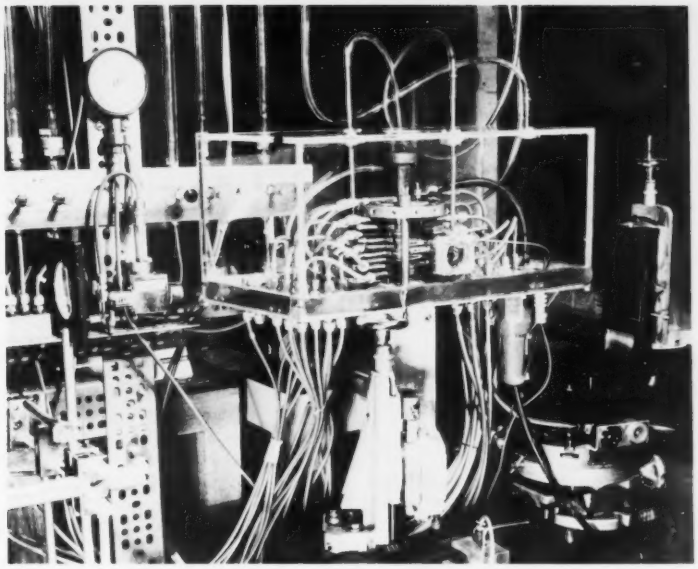
Light entering the sphere's aperture is diffusely reflected by the inner surface of the sphere and then passed through the monochromator to the detector.

(*Continued on p. 5*)

Lamp color	Chromaticity differences Spectroradiometric method minus visual method	
	Δx	Δy
Warm white	−0.002	−0.003
White	0.000	−0.004
Cool white	0.000	+0.001
Daylight	+0.002	−0.001



Schematic diagram of lamp arrangement used to standardize fluorescent lamp colors.



Experimental setup used to generate high-temperature plasmas. The plasma is contained in the cylindrical tube at the center of the glass enclosure. The tubes provide for the circulation of water for cooling and for the input of gas to the plasma area.

Data processing system speeds PLASMA STUDIES

■ A data processing system to study the light emitted by high-temperature arcs and plasmas has been designed and built [1] by D. R. Paquette and W. L. Wiese of the NBS Institute for Basic Standards. The system is fully automatic and provides a large gain in precision and in time over manual processing. Under favorable conditions it is possible with this system to obtain almost instantaneous processing of data collected in studies of inhomogeneous light sources.

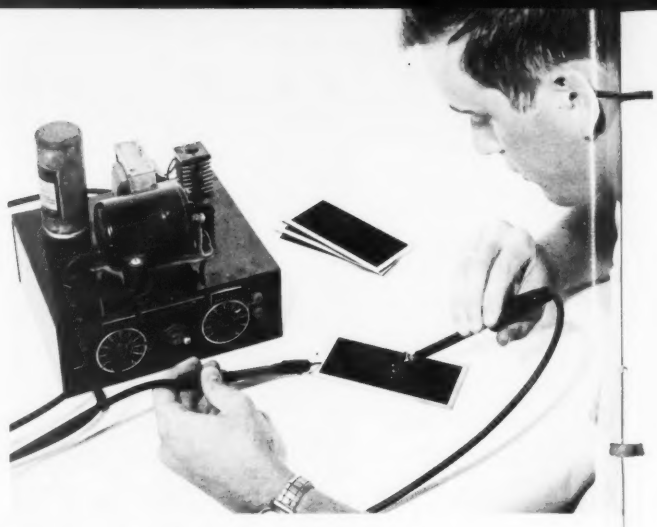
Arcs, rocket exhausts, plasma jets, and most other light sources that produce stationary hot gases or plasmas, are inhomogeneous in temperature and density. Values of these quantities are small at the periphery of the gas and highest at the center or core, decreasing outward with increasing radius. The emitted radiation thus varies from one radial zone to another.

Radiation from such light sources is studied by considering the integrated emission from the various radial zones in the plasma. For such an analysis, however, it is necessary to know the specific radiation emitted from each volume element of the plasma or gas.

To obtain this information from the observed data requires difficult and tedious mathematical analysis which consumes much more time than the experimental observations; it is therefore impossible to obtain immediate results. In the past workers have compromised on the precision of the data in an attempt to get results quickly and with as little analysis as possible. Subsequently, various computer programs were developed to reduce the analysis time and speed up the data processing. However, the preparation and read-in of the data still required a considerable amount of time and work.

Now, however, the process has been made fully automatic for rotationally symmetric plasmas. The projected intensity over a cross section of the source is photoelectrically detected and integrated over small intervals of equal length utilizing a voltage-to-frequency converter. The output is fed into a digital counter and recorded on paper tape together with auxiliary information. The data are then processed by an electronic computer using a transformation scheme which utilizes the Abel integral equation.

[1] *For further technical details, see* Data processing system for the automatic transformation of observed plasma intensities into their radial distribution, *by D. R. Paquette and W. L. Wiese, Appl. Opt.* **3**, *291 (1964).*



T. R. Davis sweeps a 25-mil thick asphalt specimen with a spark-probe tester. Photosensitive paper is placed over the specimen to record the number of cracks (sparks) in the specimen's surface.

Xenon and carbon arc

WEATHEROMETERS COMPARED

■ Scientists at the NBS Institute for Applied Technology recently compared the carbon-arc and the xenon-arc weatherometers as devices for laboratory weathering of coating-grade asphalts. The results of the study,[1] by K. G. Martin,[2] P. G. Campbell, and J. R. Wright, show general agreement between the asphalt durabilities obtained with the two sources when ASTM test methods were used. However, considerable variation in durability was detected by more sensitive analytical methods.

In a previous comparison [3] of the effects of carbon-arc, xenon-arc, and solar radiation on coating-grade asphalt, the xenon arc was shown to simulate solar radiation much better than the carbon arc. The asphalt specimens used in that study were thin films (25μ thick) rather than those described in ASTM test method D1669–62, which are 25 mils thick. As most industrial laboratories use the ASTM methods, the present study was initiated to determine which radiation source is more practical for such use.

Ten commercial coating-grade asphalts were used in this study: two Venezuelan, two Southeastern USA, three California Coastal, and three Mid-Continent USA. Specimens of these asphalts were irradiated under test conditions following ASTM test method D529–62, cycle A.

Each specimen's exposed surface was divided into 60 squares by a plastic grid overlay and was considered to have failed when 30 squares had cracks. The cracks were determined by the ASTM spark-probe method D1670–62T and durability was measured as the time lapsed before film failure.

Effects on Asphalt

For each asphalt, the effects of exposure to the xenon arc were plotted as the number of failed squares (with cracks) versus exposure time. As there were no steady cracking rates, some of the curves crossed each other. Hence, the level of crack formation selected as the failure condition will affect the relative rating of the asphalts. For instance, the 50 percent failure level gave a different order of durability than did the 25 percent level.

When carbon-arc durability was plotted against xenon-arc durability, the order of durability of asphalts from the same geographic area, considered as a group, tended to be in agreement, except for Southeastern USA asphalts. For individual asphalts within a group, however, the durabilities tended to be reversed; the asphalt most durable under carbon-arc radiation was the least durable under xenon-arc radiation.

Weatherometers

The xenon-arc weatherometer takes 1.2 times longer on the average to produce asphalt failure than does the carbon-arc weatherometer. However, the xenon-arc weatherometer's essentially continuous operation, compared to the carbon-arc weatherometer's weekend and daily shutdowns, more than offsets its slower artificial weathering. Also, the xenon source has a spectral energy distribution very similar to that of solar energy while that of the carbon-arc is unrealistically intense in the ultraviolet region (five times greater than that of the xenon arc) and lacks intensity throughout the visible and infrared regions.

The decay of radiant intensity for the xenon source, over a 2000-hour burning period, was gradual and of small magnitude after the first few hours of lamp use. Greater variation of solar radiation was observed on a clear summer day.

Thermal Shock

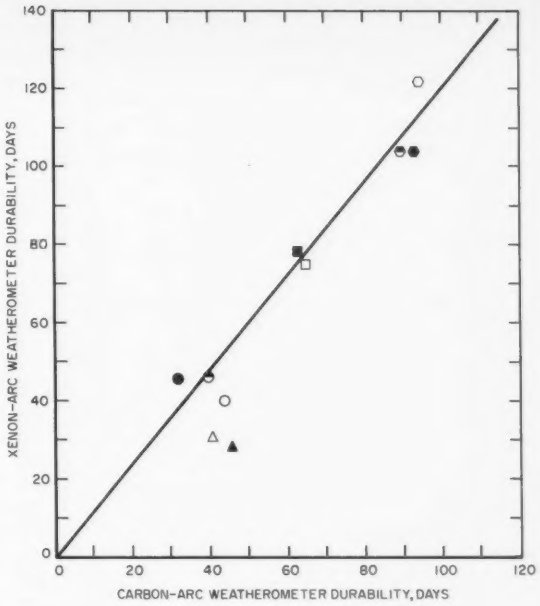
As the temperature cycle in the weatherometer is more severe than that encountered outdoors, a test series was set up to determine what effect temperature cycling alone had on the asphalts. Selected asphalts from each geographic origin were exposed to temperature cycling without irradiation. After exposure to one hundred 22-hour cycles, none of the asphalts had any cracks. The only noticeable effect was some surface dulling. Thus, thermal shock alone, without visible and ultraviolet radiation, is not a significant factor in cracking the 25-mil asphalt.

The effect of the radiant energy source on the durability of 25-mil asphalt films exposed in weatherometers (cycle A of the ASTM method) and evaluated by the spark-probe method is not readily apparent because final results are influenced greatly by other factors involved in the test method. Thus, if the ASTM test methods are used, the two machines will give comparable results. Even so, the xenon source with its "solar" spectral energy distribution should provide laboratory weathering results more closely related to natural weathering than could be expected from the more intense but less realistic carbon-arc source.

[1] *For further information, see* Comparison of xenon and carbon arcs as radiation sources for laboratory weathering of asphalts, *by K. G. Martin, P. G. Campbell, and J. R. Wright, ASTM Proceedings,* **65** *(in press).*

[2] *Present address: Division of Building Research, Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia.*

[3] Influence of radiant-energy source on bitumen oxidation, *by K. G. Martin, J. Appl. Chem. (London),* **14,** *514 (1964).*



Durabilities of asphalts exposed to xenon and carbon arc radiation tend to agree when considered in geographical groups, but within a group they tend to be reversed. Circles represent California Coastal asphalts, triangles represent Southeastern USA asphalts, squares represent Venezuelan asphalts, and the hexagons represent Mid-Continent USA asphalts.

Fluorescent lamp colors—*con.*

The detector current is indicated on a picoammeter with digital readout. A flat-plate recorder is also used with the instrument to facilitate evaluation of the energy in the mercury lines of the fluorescent lamp.

An incandescent lamp operated at a known color temperature is used as the standard light source. To carry out a calibration, the fluorescent lamp under test is mounted on a bench above the aperture in the sphere. The incandescent lamp is mounted to one side of the sphere on a horizontal line through the sphere's center. The fluorescent lamp is installed in a well-ventilated draft-free enclosure and operated at a constant current. Both lamps are operated continuously; light shields are used to prevent interreflection. Lamps and equipment are turned on for at least 20 minutes before data are recorded.

The radiant flux from each source is measured at 10-nm intervals over the spectral range 400 to 700 nm. The sphere is rotated manually 90 degrees at each wavelength interval to obtain a measure of the relative spectral irradiance of the fluorescent lamp and of the incandescent lamp. The intensity of each mercury line is computed from the area under the curve in the region of the line. The time required to obtain relative spectral irradiance data for one fluorescent lamp depends on the skill of the operator, but it usually takes from 30 to 60 minutes. The chromaticity coordinates of the lamp are then computed.

The differences between the chromaticities found by the spectroradiometric method and by the visual method for the NBS fluorescent lamp color standards are given in the table.

The chromaticity values assigned to the NBS standards have been corrected by the amounts shown in the table. Similar standards are used by U.S. fluorescent lamp manufacturers to control the colors of the lamps they produce. The chromaticity differences listed in the table have been transmitted to these manufacturers so that similar corrections can be made to the values assigned to their standards.

CLEARINGHOUSE
FOR FEDERAL SCIENTIFIC AND TECHNICAL INFORMATION

Internship Program

For Recent Science and Engineering Graduates, Documentalists, and Science Librarians

PURPOSE.—Through this program, recent science and engineering graduates, documentalists, librarians, and information scientists are given the opportunity to acquire firsthand knowledge and work experience in the operation of the Clearinghouse for Federal Scientific and Technical Information, the national center for the dissemination of Government-generated information on science and technology. Current activities at the Clearinghouse, employing modern methods of handling large volumes of scientific and technical information, can provide a challenging work experience for graduates desiring to make a career in information science.

Specifically, the Internship Program aims to: provide through proper training, a broadly based work experience upon which the intern can build a career in documentation and information handling; develop skills in advanced documentation techniques; give the intern an intensified, systematic working knowledge of Federal documentation activity; acquaint the intern with the character of the Clearinghouse in its interaction with the major information retrieval systems of the Nation; develop a select group of individuals who may be considered for permanent appointment in important, rapidly growing programs at the Clearinghouse.

Authority for this program is through the Government Employees Training Act, as amended (Public Law 85–507, approved July 7, 1958).

PROGRAM CONTENT.—The Internship Program is divided into two phases, each lasting six months.

Orientation and Introductory Work Assignment.—Tour of the Clearinghouse with introduction to its organization and the functions of its various branches in carrying out its mission; a series of rotating work assignments in each of its branches; seminars and lectures conducted by members of the Clearinghouse staff, by guest documentalists, and by guest lecturers from the technical divisions of the National Bureau of Standards; a reading program; field trips to major information-handling organizations in the Washington area.

Intensive Work Assignments.—A six-month intensive working experience in a specific section of the Clearinghouse, in a position related to the intern's special interest and competence, for interns of unusually high competence, opportunity to participate in a special program to test the results of prior documentation research. Examples of possible assignments are: comparative studies of computer methods versus semi-automatic methods versus manual methods of handling information; tests of the effectiveness of various procedures for selective dissemination of information; feasibility studies relating to large-scaled cooperative efforts in handling information.

DURATION OF ASSIGNMENT AND PROGRAM APPRAISAL.—The total length of the training program will be 12 months. At the conclusion of each introductory work assignment, the intern will make an oral report to the Chief of the branch to which he has been assigned. At the end of the six-month intensive training period, the intern will prepare a written evaluation of the Intern Training Program and submit it to the Director of the Clearinghouse. A written evaluation of each intern's progress will be prepared by the principal administrator of each organizational unit to which the intern is assigned.

ELIGIBILITY AND SELECTION.—Recent college graduates in the physical sciences or engineering, and recent graduates of library schools, and schools of information science are invited to apply. Deans of graduate schools of science and engineering, deans of library schools, and directors of institutions offering graduate programs in information science in the United States are invited to nominate outstanding graduates as interns.

Applicants should submit the following:

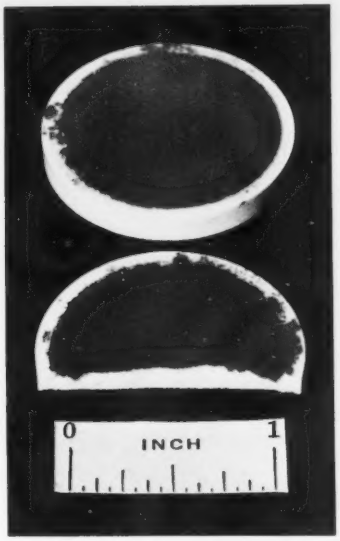
Standard Form 57 (available from local Civil Service Office or U.S. Post Office)

Transcript of college record.

Nominees will be further evaluated by personal interview, personal references, etc., to ensure that only individuals with high potential and a genuine interest in professional documentation are selected. All candidates must be United States citizens.

Appointments will be made for one year in the Civil Service grades of GS–5 ($5,181 per annum), GS–7 ($6,269 per annum), or GS–9 ($7,479 per annum). The grade level will depend upon the applicant's education and experience. Applicants must meet current Civil Service requirements at the appropriate grade.

Applications must be submitted by March 1 to Mr. Bernard M. Fry, Director, Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia, 22151. Applicants should be available by September 15, although earlier appointments for June graduates may be arranged.



Sturdy samples of pressed cement powder have edges and backing of compressed boric acid crystals and may be used indefinitely without crumbling.

STURDY POWDER CEMENT SPECIMENS

for x-ray analysis

■ A method of producing sturdy specimens of pressed cement powder for x-ray spectrochemical analysis has been developed by Leonard Bean of the NBS Institute for Applied Technology. The specimens are not diluted with a binder; thus, a high intensity of fluorescent x radiation is obtainable.[1] The method should be useful for preparing pressed powder specimens of other materials for x-ray spectrochemical analysis.

Studies have shown that x-ray spectrochemical analysis is suitable as a routine test to determine the constituents of cement.[2] This technique furnishes information about certain of these constituents not ordinarily determined by chemical methods and permits more thorough evaluation of a cement test sample. However, until the method of preparing sturdy specimens was developed, the specimens, often shattered during the pressing operation or else crumbled around the edges after a few tests.

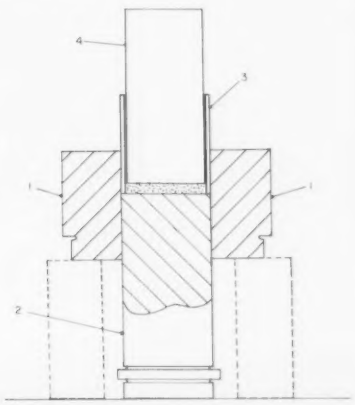
The new specimens have edges and a backing of compressed boric acid crystals. The surface of the boric acid edges functions as a lubricant so that the rate of application or release of pressure during pressing is no longer critical and shattering is unlikely. The boric acid edges and backing support the pressure of the sample holder so that the samples may be used indefinitely without crumbling.

The method of producing sturdy specimens of pressed powder is as follows: A sleeve with sides about 0.16 cm thick and outside diameter 0.02 cm less than the inside diameter of the mold is placed in the mold. The powder to be analyzed (usually about 2 g) is spread on the lower plunger of the mold. This may be done by pressing gently with a loose fitting plunger or spreading with the end of a spatula. If a plunger is used, it is usually necessary to scrape the inside of the sleeve in contact with the lower plunger with the tip of a stiff wire to separate the compacted powder from the sleeve. The sleeve is rotated slightly and then removed. Boric acid crystals (about 5 ml) are then poured into the peripheral trench and on top of the powder. The specimen is then pressed to the pressure desired. In the preparation of samples at the Bureau using this method, pressures from 5,000 to 70,000 psi were used.

[1] A method of producing sturdy specimens of pressed powders for use in x-ray spectrochemical analysis, *by Leonard Bean, Journal of Applied Spectroscopy (in press).*

[2] X-ray spectrochemical analysis of cement, *by Leonard Bean and Barry W. Mulligan, NBS Tech. News Bull.,* **48,** *73 (May 1964).*

Apparatus (schematic) used to obtain pressed cement powder specimens for x-ray analysis. (1) Main body of mold; (2) lower press plunger; (3) steel sleeve; (4) steel plunger for hand tamping sample.



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Top: *A double exposure of a yarn specimen, marked at intervals along its length, shown before and after impact. The bullet may be seen at the vertex of the V-shaped wave of transverse motion, only one-half of which is shown in the photograph. The path of the bullet is indicated by the arrow.*

■ The fabrics employed today for flexible body armor, for astronauts' suits, and for spacecraft retrieval parachutes must absorb large amounts of high-velocity impact shock. To measure this absorption, C. A. Fenstermaker, J. C. Smith, and P. J. Shouse of the NBS Institute of Materials Research have been shooting rifle bullets at textile yarns and using flash photography to record the resulting motion. In this way they have obtained data which throw new light on the impact behavior of high-strength textiles, disproving beliefs held in the past. These results should aid in the development of materials having even better impact properties [1] than those now available.

In a series of tests, a two-meter yarn specimen marked at intervals along its length was photographed before and shortly after impact, to obtain a double ex-

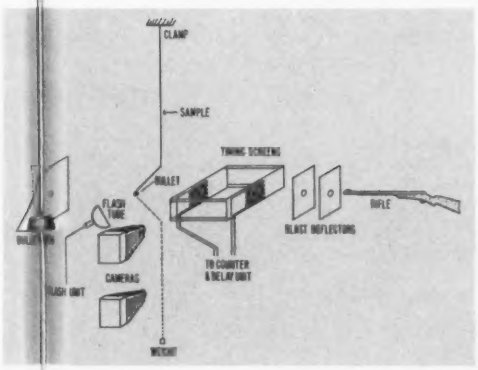
Left: *C. A. Fenstermaker clamps a yarn specimen into its holder.* Far right: *P. J. Shouse sights a specimen through the bore of the rifle used in the tests. Schematic* (center) *illustrates equipment used to study the impact behavior of high-tenacity yarns.*

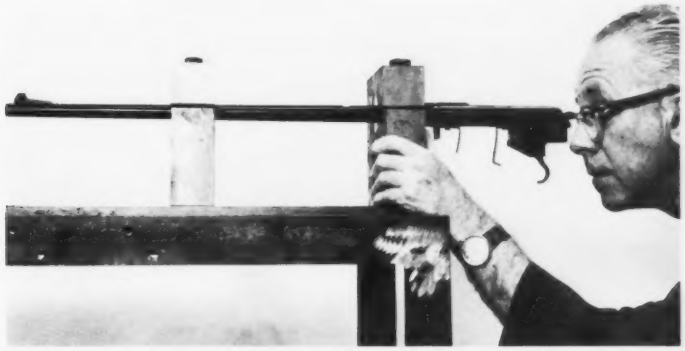
MPACT BEHAVIOR

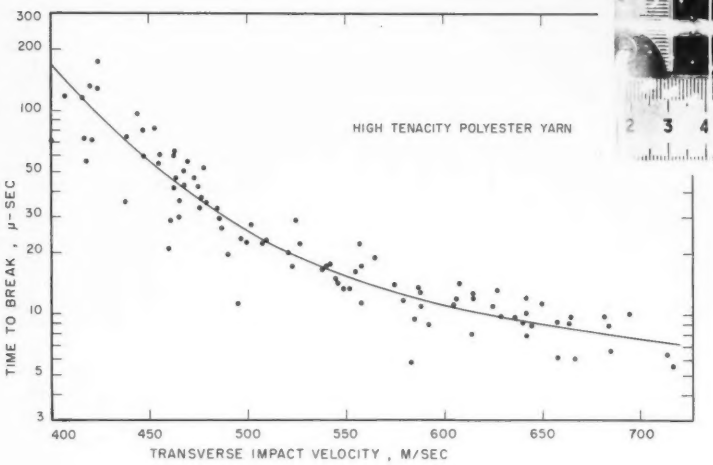
posure. Distance calibration along the yarn and in the direction of bullet travel was provided by two scales photographed in the plane of impact during the preimpact exposure. The scales were then removed and the yarn displaced slightly before firing the rifle and photographing the second exposure.

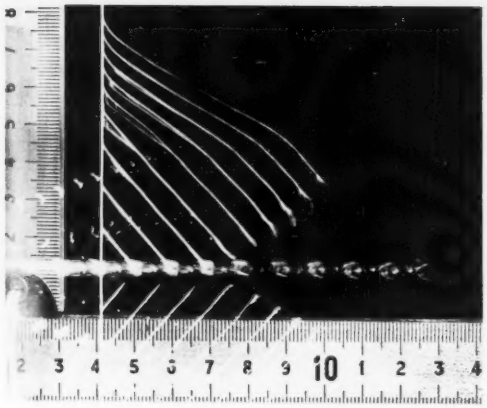
High-tenacity polyester yarn was used as a specimen in one of these tests. The postimpact exposure was taken 169 microseconds after impact at 370 m/sec velocity. Over most of the specimen length the marks after impact were displaced from their previous positions, indicating that the passage of a strain wave had caused yarn material to flow towards the point of impact. This displaced material formed itself into a V-shaped wave of transverse motion with the bullet at the vertex of the V. Measurements showed that the strain wavefront had traveled 65.3 cm, thus its velocity was 3860 m/sec. The complete distribution of strain in the wave was determined from measurements of the relative displacement of each mark on the specimen.

With this procedure, the investigators derived numerous strain distributions at various impact velocities and at various times after impact for both high-tenacity polyester and nylon yarns. An analysis of these distributions showed that, contrary to previous belief, yarns apparently undergo both creep and stress relaxation within the first 30 μsec after impact. The analysis also indicated that, at impact velocities of 175 m/sec, creep at the point of impact was about 15 percent and stress relaxation about 5 percent.









Left: *Graph shows how the breaking times of textile yarns decrease with increasing impact velocities.* Right: *Multiflash photograph of a high-tenacity polyester yarn being impacted by a rifle bullet at 439 m/sec velocity. The bullet's path is clearly visible. The time between flashes was 21.7 microseconds; the specimen broke after 74 microseconds.*

In a second series of tests with high-tenacity yarns, multiflash pictures were taken. A similar procedure was used, except that the specimens were not marked and the flashes were triggered in a sequence of short-time intervals starting just before impact. Thus specimen breakage at high velocities and at short times after impact could be observed. For example, in one photograph in which the time between flashes was 21.7 μsec, a specimen struck at a velocity of 439 m/sec was observed to break 74 μsec after impact.

Test results showed that the time required for specimen breakage depended on the velocity of the bullet. For instance, when the bullet struck a polyester yarn specimen at 420 m/sec, breakage did not occur until 100 μsec had elapsed, but when the impact velocity was 620 m/sec, breakage occurred within 10 μsec. This finding is also contrary to previous belief that at particular "critical" velocities high-tenacity yarns would break immediately upon impact.[2] Thus, the present work shows that these yarns exhibit creep and stress relaxation characteristics, even though they are of microsecond duration.

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[1] *For further details, see* Stress-strain properties of textile yarns subjected to rifle bullet impact, *by C. A. Fenstermaker and J. C. Smith, J. of Applied Polymer Science (in press). Also, see* Stress-strain relationships in yarns subjected to rapid impact loading, Part XI: Strain distributions resulting from rifle bullet impact, *by J. C. Smith, C. A. Fenstermaker, and P. J. Shouse, Textile Research Journal* **35,** *743 (1965), and* Part X: Stress-strain curves obtained by impacts with rifle bullets, *by J. C. Smith, C. A. Fenstermaker, and P. J. Shouse, Textile Research Journal* **33,** *919 (1963).*

[2] Shock loading of textile yarns, *NBS Tech. News Bull.* **40,** *91 (1956).*

SPECTRAL DATA

obtained for

space probes

■ A tool that may prove useful for future space probes has been devised in recent research at the NBS Institute for Basic Standards. In this work, D. M. Gates,* H. J. Keegan, and V. R. Weidner of the NBS staff measured the light-reflecting and absorbing properties of plants, animals, and minerals as a function of wavelength.[1] The resulting curves have distinctive infrared features which are, in effect, fingerprints of these substances. Thus spacecraft equipped to record and compare spectral data could quickly detect the presence or absence of naturally occurring substances on extraterrestrial surfaces if they are biochemically akin to their terrestrial counterparts.

Astronomers have long been recording the spectral characteristics of other planets by means of telescopic observations. The absorption band patterns thus derived, however, have not been conclusive; first, because of the great distances involved, and second, because of possible interference from elements in the earth's own atmosphere. The present work was therefore undertaken to derive data for comparison with data gathered in future space probes. Other types of matter whose spectral characteristics have not been delineated will be studied in subsequent work.

The plant specimens chosen for the study were representative of typical vegetation on the earth's surface, including deciduous and evergreen leaves, fungus, bark, moss, algae, and lichen. Animal integuments investigated included feathers, furs, sea shells, and lizard and human skins. Mineral specimens were made from feldspar, soil, polished malachite, and iron ore (limonite).

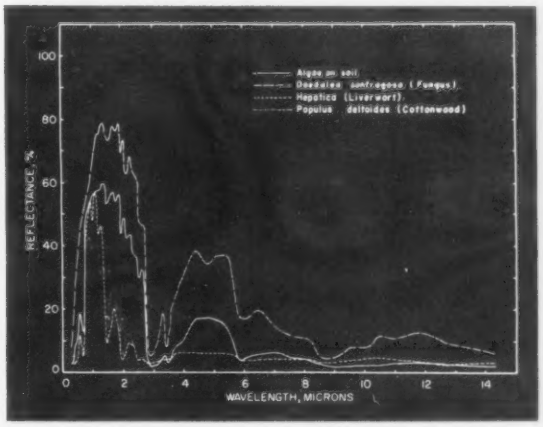
Instrumentation

In the experiments, three different spectrophotometers were used to measure the spectral characteristics of the specimens in the visible region, and in parts of the ultraviolet and infrared. A special attachment [2] was fitted to the instrument used for the infrared measurements so that the radiant energy emitted by the specimens in this region was excluded; such emission would have affected measurement accuracy. When small differences in spectra were obtained with any two of the instruments at a juncture or overlap in the measurements, the individual values thus obtained were averaged for a small wavelength distance on either end of the spectra.

(*Continued on p. 14*)

V. R. Weidner inserts a leaf on its holder into a specially designed hemisphere in a spectrophotometer to obtain infrared spectra.

Graph shows the spectral reflectances found for various kinds of plants in the study.



Standards and Calibration

Use of ac-dc transfer instruments

E. S. Williams of the Electrical Instruments Section (NBS Institute for Basic Standards) has prepared a pamphlet of practical advice for the user of electrothermic transfer instruments, devices whose major application is the making of direct measurements of ac-dc difference or frequency influence in the readings of ammeters and voltmeters. By a somewhat similar procedure one can use transfer instruments to accurately measure an a-c voltage or current by determining the difference between it and a preset and accurately measured d-c equivalent. In 10 pages the pamphlet describes test circuits and procedures for performing these measurements and gives illustrations of data taking and calculations. The publication is NBS Technical Note 257, *Practical Aspects of the Use of AC-DC Transfer Instruments*, and is obtainable at 15 cents per copy from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402.

Microwave impedance

The recently issued NBS Monograph 82, *Microwave Impedance Measurements and Standards*, by Robert W. Beatty of the IBS Radio Standards Engineering Division, is a 31-page tutorial review of well-known microwave impedance measurement techniques, preceded by an introduction that emphasizes basic concepts and reflection coefficient-VSWR relationships. Sources of error in the various measurement techniques are discussed and information is given on how the errors can be reduced. Errors in slotted-line and reflectometer techniques are treated at greater length. Attention is also given to methods of using rotating loops and resonance lines, and there is a short discussion of microwave impedance standards. The publication is obtainable at 20 cents per copy from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402.

Calibration of coaxial bolometer mounts

The Radio Standards Laboratory announces that an additional service is now available for the measurement of the calibration factor [1] of nominal 50-ohm coaxial bolometer units. The new service provides for calibration at 3 GHz, in addition to the frequencies of 100 MHz and 1 GHz that have been available for a number of months. Measurements are made at the 1 and 10 milliwatt power levels only, with no provision at present for the calibration of bolometer-coupler units.

The limit of uncertainty in determining the calibration factor at 3 GHz is within 1.5 percent for well-designed bolometer units. Limits of uncertainty may be greater for bolometer units having a VSWR higher than 1.1. The service includes the calibration of both barretter and thermistor types of bolometer units having operating resistances of 50, 100, and 200 Ω.

Low-frequency calibration services centralized

The Electronic Calibration Center (ECC) of the NBS Radio Standards Laboratory at Boulder, Colorado, as its customers have already been informed, no longer accepts for calibration low-frequency (0 to 30 kHz) interlaboratory standards and instruments—with the sole exception of frequency stability calibration of signal sources.[2] The change has been made for reasons of economy and managerial efficiency.

All low-frequency standards and instruments, with the exceptions noted, should now be submitted for calibration to: Electricity Division, Institute for Basic Standards, National Bureau of Standards, Washington, D.C., 20234. Since the Electricity Division is just beginning the complex process of moving to the new NBS laboratories at Gaithersburg, Maryland, it has asked that, during the next few months, requests be submitted only for the most urgently needed calibration. The transfer to Gaithersburg is expected to be completed by the end of June 1966.

It is emphasized that the high-frequency and microwave calibrations provided by the ECC are not affected by this change. That is, all calibration services at frequencies above 30 kHz will continue to be available, as in the past, only at the Electronic Calibration Center, Radio Standards Laboratory, NBS, Boulder, Colorado.

Catalog of calibration services revised

A revision (known as the "1965 Edition") of NBS Miscellaneous Publication 250, *Calibration and Test Services of the National Bureau of Standards*, is available for distribution. Compiled from official announcements that originally appeared in the *Federal Register*, the revised MP250 is in effect a 135-page catalog of NBS calibration and test services [3] as of the beginning of 1966.

Besides describing the different services, the publication contains general information of importance to prospective users of the services. Among other things, it summarizes NBS policy on test and calibration services, tells how to proceed in requesting a service; gives instructions for identifying, packing, shipping, and insuring the equipment submitted; explains the purpose and nature of the NBS report on a test or calibration (several recent reports, with clients' names deleted, are reproduced as illustrations); indicates minimum billing charges; lists the established fees; and gives the location of laboratories. It also outlines the functions of

NBS and its various institutes and provides bibliographical information on publications mentioned in connection with particular services. There is an index as well as a table of contents.

A feature of the 1965 Edition of MP250 is that the fees are listed separately in an appendix. This makes it possible to prepare revised fee lists, as they become necessary, without having to reprint the entire document. Also, as individual services are modified or new ones added, "Insert Sheets" describing these changes will be distributed without charge to those who have submitted the postcard provided for that purpose with each copy of MP250.

The publication is perforated for insertion, if desired, in a three-ring binder, and the same will be done with supplementary fee lists and inserts. Copies of the 1965 Edition of MP250 are available at $1.00 each from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402.

Changes in radio broadcasts

In accordance with the National Bureau of Standards policy of giving monthly notices regarding changes of phases in seconds pulses, notice is hereby given that there was no change in the phase of seconds pulses emitted from radio station WWVB, Fort Collins, Colorado, on January 1, 1966. The successive time pulses emitted from station WWVB are one second apart. The carrier frequency of WWVB is 60 kHz, and is broadcast without offset.

Notice is also hereby given that there was no adjustment in the phases of time signals emitted from radio stations WWV, Greenbelt, Maryland, and WWVH, Maui, Hawaii, on January 1, 1966. However, on January 1, 1966, a change was made in the time interval between these pulses. During 1965, the pulses from these stations occurred at intervals which were longer than a second by 150 parts in 10^{10}. During 1966, the pulses will occur at intervals which are longer than one second by 300 parts in 10^{10}, due to the new offset to be maintained in carrier frequencies, as coordinated by the BIH.

Phase adjustments, when made, ensure that the emitted pulses from all stations will remain within about 100 ms of the UT2 scale. They are made necessary because of changes in the speed of rotation of the earth with which the UT2 scale is associated. Daily UT2 information is obtained from weekly forecasts of UT2 provided by the U.S. Naval Observatory in accordance with the close cooperation maintained between the two agencies.

Precision Measurement Seminars underway

A seminar on low-frequency electrical standards, first in the 1965–66 series of NBS Precision Measurement Seminars, took place as scheduled December 8–10, 1965. Despite the relatively short time between the announcement of the seminars (in the September 1965 *NBS Technical News Bulletin*) and the date of first seminar, the list of registrants numbered 50.

Registers for the remaining seminars are now nearly full. Those planning to apply are urged to do so at once.

Vacuum calibration service extended

To meet needs of industrial scientific programs for improved vacuum measurements, the NBS Institute for Basic Standards is extending its calibration service over a greater portion of the vacuum range. Initially, the extended service will cover pressures from 1 to 1,000 millitorr (0.133 to 133 N/m^2).[4] Typical industrial processes in which this pressure range occurs are the preparation of vacuum-melt steel and freeze drying. The same pressure range, 1 to 1,000 millitorr, is also important in the development of aerospace equipment since it corresponds to an altitude range of roughly 45 to 90 km (150,000 to 300,000 feet).

Measurement of microwave power in WR137 waveguide

The Radio Standards Laboratory of the NBS Institute for Basic Standards, Boulder, Colorado, announces a calibration service in WR137 waveguide for the measurement of effective efficiency, efficiency, and calibration factor of bolometer units and of calibration factor of bolometer-coupler units. The measurement of efficiency of a bolometer unit is made available for the first time by the Radio Standards Laboratory, but for the present is limited to WR137 waveguide. Although calibrations can be performed within the useful range of the waveguide, some degree of economy to the customer results if calibrations are performed at the selected [5] frequencies of 6.45, 7.00, and 7.40 GHz.

The four quantities measured are defined as follows:

Effective Efficiency for Bolometer Units: The ratio of the substituted d-c power in the bolometer unit to the microwave power dissipated within the bolometer unit.

Calibration Factor for Bolometer Units: The ratio of the substituted d-c power in the bolometer unit to the microwave power incident upon the bolometer unit.

Efficiency for Bolometer Units: The ratio of the microwave power absorbed by the barretter element to the microwave power dissipated within the bolometer unit.

Calibration Factor for Bolometer-Coupler Units: The ratio of the substituted d-c power in the bolometer unit on the side arm of the directional coupler to the microwave power incident upon a nonreflecting load attached to the output port of the main arm.

Because of certain limitations in adapting the microwave microcalorimeter measurement technique to the larger waveguide sizes, the effective efficiency and calibration factor of bolometer units in WR137 waveguide are measured somewhat indirectly by using a working standard that has been calibrated by the impedance method.[6, 7, 8] The impedance technique yields a direct measurement of the efficiency of a bolometer unit. This efficiency measurement, usually of special interest only, is available for the first time at the Radio Standards Laboratory as a calibration service. The bolometer units must be fitted with a barretter element of a purely resistive type (thermistor-type element cannot be used) with a nominal resistance of 200 Ω. The efficiency

measurements are performed with an uncertainty no greater than ±1 percent.

The effective efficiency and calibration factor of a bolometer unit, as well as the calibration factor of a bolometer-coupler unit, are measured with an uncertainty no greater than 2 percent in WR137 waveguide. For these measurements the element can be of the barretter or thermistor type, and of either 100- or 200-Ω resistance, operating at a bias current between 3.5 and 15 mA. The bolometer unit can be of either the fixed-tuned or untuned broadband type. Power measurements can be made on bolometer units over a range of 0.1 to 10 mW.

Power measurements can be made on bolometer-coupler units in WR137 waveguide with coupling ratios from 3 to 20 dB. A bolometer unit of either the fixed-tuned or untuned broadband type must be permanently attached to the side arm of the coupler. The coupler should have a directivity of no less than 40 dB, and a VSWR no greater than 1.05 for the input and output ports of the main arm of the coupler.

[1] *The calibration factor of a bolometer unit is defined as the ratio of the substituted d-c power in the unit to the rf power incident upon the bolometer unit.*

[2] *The excepted services are covered in section 201.701 of the NBS fee schedules.*

[3] *It does not, however, describe the standard reference materials supplied by NBS. These are covered in a separate publication, NBS Miscellaneous Publication 260,* Catalog and Price List of Standard Materials Issued by the National Bureau of Standards, *for sale at 45 cents per copy by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402.*

[4] *Or 1/760,000 to 1/760 atm.*

[5] *In performing microwave calibrations, a considerable amount of time is usually needed to prepare the system for a measurement operation. Much of this preparation is related to adjustment of the system to the frequency of operation selected for the calibration. Time and cost often can be reduced by minimizing the number of times the operating frequency of the calibration system must be readjusted.*

[6] Determination of efficiency of microwave bolometer mounts from impedance data, *by David M. Kerns, NBS J. Res.* **42,** *579 (1949), RP 1995.*

[7] An improved method of measuring efficiencies of ultra-high-frequency and microwave bolometer mounts, *by R. W. Beatty and Frank Reggia, NBS J. Res.* **54,** *321 (1955) RP 2594.*

[8] A bolometer mount efficiency measurement technique, *by G. F. Engen, NBS J. Res.* **65C,** *113 (1961).*

Spectral data—con.

Experimental Results

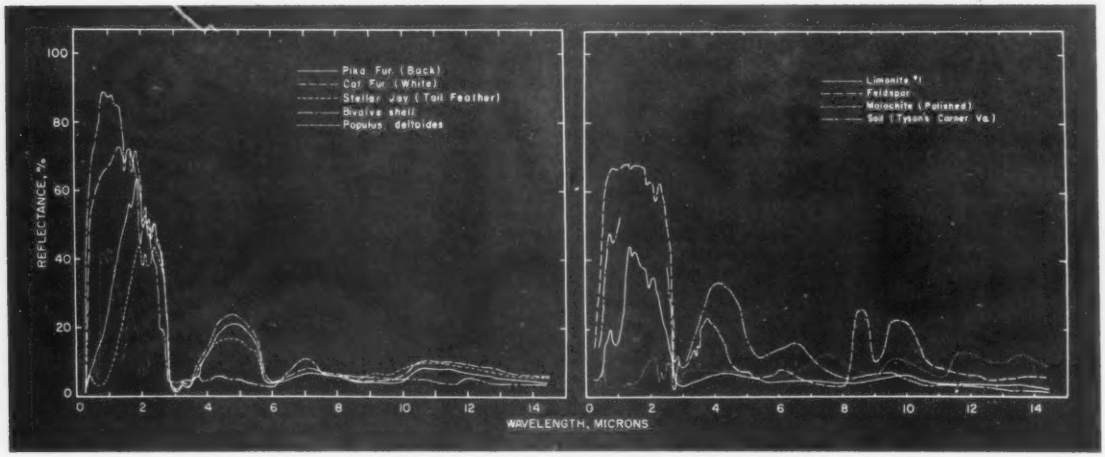
The spectral reflectances obtained in the experiments showed one common feature: in practically all the specimens, peak reflection bands occurred between 1000 and 2000 nanometers (1.0 to 2.0 microns) in the infrared. The peak of the fungus approached 80 percent, that of the sea shell 90 percent, and that of the feldspar 70 percent.

A striking similarity in the spectra of both plant and animal specimens occurred at about 3500 nm (3.5 microns) in the infrared. At this wavelength, both types exhibited marked absorption bands, due to the presence of water and organic molecules. The spectra also showed that only plants pigmented with chlorophyll demonstrate an abrupt change in reflectance at the red end of the visible spectrum. At 700 nm (0.7 micron) these plants had sharp absorption bands that were not apparent in any of the other materials.

*Now on the faculty of Washington University, St. Louis, Mo.

[1] *For further details, see* Spectral reflectance and planetary reconnaissance, *by D. M. Gates, H. J. Keegan, and V. R. Weidner, to be published in the Proceedings of the Third Goddard Memorial Symposium of the American Astronautical Society, P. C. Badgeley, NASA Headquarters, Editor, 1965.*

[2] New method for measuring diffuse reflectance in the infrared, *by J. U. White, J. Opt. Soc. Am.* **54,** *1332 (Nov. 1964).*



Left: *The spectral reflectances for animal integuments are shown here as a function of wavelength. The reflectance of a green plant leaf (populus deltoides) is included for comparison purposes.* Right: *This graph shows the spectral reflectance for various minerals. Significant features common to all three of these graphs are the peak reflection bands that occur between 1 and 2 microns (1000 to 2000 nm).*

WWVB adds

TIME CODE

to broadcasts

David H. Andrews prepares to photograph an oscilloscope presentation of the time-code modulation broadcast. Mr. Andrews makes several such checks daily to verify that the proper modulation pattern is being applied.

■ Time information has been broadcast by the Bureau since 1935, with many subsequent improvements in its accuracy and precision. As a further step in improving its service to users of frequency and time broadcasts, NBS radio station WWVB, Fort Collins, Colo., is now broadcasting time-of-day information. The broadcast gives the minute, hour, day of the year, and milliseconds difference of UT2 from the uniform time scale of WWVB in a carrier level-shift time code, a system devised by David H. Andrews, who heads the Bureau's Frequency-Time Broadcast Services' Section.

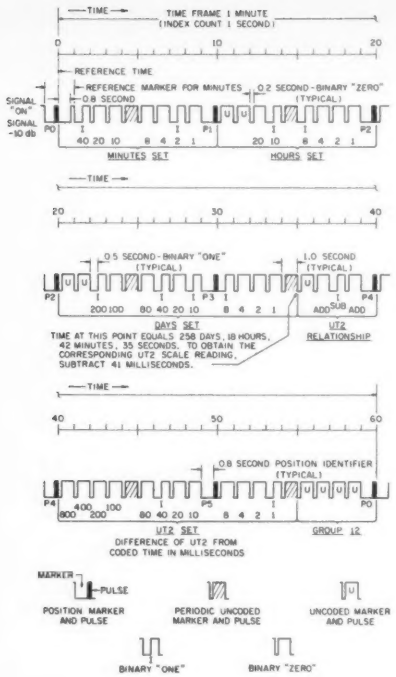
The new code permits users all over the United States to record events automatically against a uniform time scale. WWVB's signals thus constitute, in effect, the standard clock for the United States. For example, in geophysical research, with widely spaced recording stations, event recordings can be synchronized with greater accuracy than ever before. It is also possible to date and time communications traffic on multichannel recorders with pinpoint accuracy—an important legal consideration for some agencies and an important research consideration for others.

The Radio Standards Laboratory (RSL) of the NBS Institute for Basic Standards is responsible for establishing, maintaining, and disseminating the Nation's standards of frequency and time. The thousands of users of these standards in the electronics industry include manufacturers of electronic equipment, electric power companies, and radio and TV networks. Many government agencies, such as the Federal Aviation Agency, the Department of Defense, and the National Aeronautics and Space Administration, also make extensive use of the service.

WWVB is one of four radio stations operated by RSL's Frequency-Time Broadcast Services Section. WWVB might be called the NBS master station, since the broadcasts of WWV (Greenbelt, Md.) and WWVH (Maui, Hawaii) are, in effect, controlled by the signals from WWVB. Redundant information also is received from WWVL, which is an experimental VLF station likewise located at Fort Collins, Colo. WWVB and WWVL, in turn, are tied directly by phaselock equipment to the United States Frequency Standard (USFS), an atomic device located in the Boulder (Colo.) Laboratories. WWVB broadcasts include a standard carrier frequency and standard one-second intervals derived from the USFS.

The new modulation of WWVB signals is obtained from three identical time-code generators, provided jointly by the Bureau and the U.S. Department of the Interior. These generators, the outputs of which are constantly compared with each other, provide the degree of reliability so essential to standard frequency and time broadcasting.

The time-coding equipment is unique in several respects. The units receive as inputs the same frequency (60 kHz, without offset) which is broadcast from WWVB. This frequency is divided to obtain time pulses occurring at regular one-second intervals, instead of the slightly longer intervals heard on broadcasts of stations whose carrier frequencies are offset from their nominal values. This offset is changed each year so that time pulses derived from these offset frequencies



Time-scale representation of carrier level-shift modulation. BCD code gives time, day, and difference between WWVB and UT2 time scales.

occur at a rate throughout each year which approximates the slightly variable scale known as UT2. (UT2, also known as Greenwich Mean Time, is the adjusted mean solar time scale based on the rotation of the earth.)

Station identification is still made by a characteristic carrier phase advance followed by an identical retardation at periodic intervals, without keyed interruption of the carrier.

Two new features have been incorporated, one of which is automatic "UT2 difference" insertion. Differences of UT2 from the uniform time scale of WWVB are obtained from U.S. Naval Observatory data and are entered on dials on the front panel of the time-code generators by the operators each day at any convenient time. At exactly 2400 UT these differences are entered automatically into the generator circuitry and control the code broadcast during the subsequent 24 hours.

The other feature is automatic 200-ms time retardation. When a time retardation is required on the first of a month, in order to keep the uniform scale within 0.1 second of UT2, the operator sets a switch during the day preceding the time adjustment. Exactly at 2400 UT the 200-ms time retardation is automatically programmed into the time code being generated.

Except for the UT2 difference information, these generators operate in very similar fashion to other time-code generators which are used for time recording on the Atlantic and Pacific Missile Ranges and Satellite Tracking Stations. They provide time-of-day information in minutes and hours, as well as the day of the year.

The code, binary coded decimal (BCD), is synchronized with the 60 kHz carrier signal and is broadcast continuously. The new system replaces the method whereby seconds pulses of uniform width were broadcast by level-shift carrier keying. The carrier is no longer interrupted for keyed station identification, since the characteristic phase advance by 45° at 10 minutes after every hour, followed by a similar phase retardation 5 minutes later, continues to identify the station.

Publications of the National Bureau of Standards

Periodicals

Technical News Bulletin, Volume **49**, No. 12, December 1965. 15 cents. Annual subscription: $1.50, 75 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.

Journal of Research of the National Bureau of Standards

Section A. Physics and Chemistry. Issued six times a year. Annual subscription: Domestic, $5; foreign, $6. Single copy, 75 cents.

Section B. Mathematics and Mathematical Physics. Issued quarterly. Annual subscription: Domestic, $2.25; foreign, $2.75. Single copy, 75 cents.

Section C. Engineering and Instrumentation. Issued quarterly. Annual subscription: Domestic, $2.75; foreign, $3.50. Single copy, 75 cents.

Current Issues of the Journal of Research

J. Res. NBS **70A** *(Phys. and Chem.), No. 1 (Jan.–Mar. 1966).*

Optional and magnetic spectra of bis-N-propylsalicylaldiminato copper (II). C. W. Reimann, G. F. Kokoszka, and H. C. Allen, Jr.

Phase equilibria in the system niobium pentroxide-germanium dioxide. E. M. Levin.

Phase equilibria in the system niobium pentroxide-boric oxide. E. M. Levin.

The solution to a nonlinear Lamm equation in the Faxen approximation. I. H. Billick and G. H. Weiss.

A line formula notation system for coordination compounds: III Deviations from idealized configurations. E. Silverton and R. F. Pasternack.

The spherulitic crystallization of isotactic polypropylene from solution: On the evolution of monoclinic spherulites from dendritic chain-folded crystal precursors. F. Khoury.

Wavelengths, intensities, and Zeeman patterns in ytterbium spectra (Yb I, II, III, IV). W. F. Meggers and C. H. Corliss.

J. Res. NBS **70C** *(Engr. and Instr.), No. 1 (Jan.–Mar. 1966).*

Coulometric calibration of microvolumetric apparatus. G. Marinenko and J. K. Taylor.

Effect of temperature and notch geometry on the tensile behavior of a titanium alloy. W. D. Jenkins and W. A. Willard.

Measurement standards for low and medium peak pulse voltages. A. R. Ondrejka and P. A. Hudson.

Temperature coefficient of rf permeability measurement using an impedance bridge as an equality indicating device. A. L. Rasmussen.

A test apparatus for the study of forced air-mixing devices. T. K. Faison, J. C. Davis, and P. R. Achenbach.

Other NBS Publications

Calibration and test services of the National Bureau of Standards, NBS Misc. Publ. 250, 1965 Edition (Oct. 28, 1965). $1.00. Supersedes 1963 edition.

Standard Reference Materials: Methods for the chemical analysis of NBS copper-base spectrochemical standards, R. K. Bell, NBS Misc. Publ. 260–7 (Oct. 25, 1965), 60 cents.

Standard Reference Materials: Half lives of materials used in the preparation of standard reference materials of nineteen radioactive nuclides issued by the National Bureau of Standards, S. C. Anspach, L. M. Cavallo, S. B. Garfinkel, J. M. R. Hutchinson, and C. N. Smith, NBS Misc. Publ. 260–9 (Nov. 15, 1965), 15 cents.

Automotive lifts, CS142–65 (Sept. 1, 1965), 10 cents. Supersedes CS142–62.

Acrylonitrile-butadiene-styrene (ABS) plastic drain, waste, and vent pipe and fittings, CS270–65 (Apr. 1, 1965). 15 cents.

Polyvinyl chloride (PVC) plastic drain, waste, and vent pipe and fittings, CS272–65 (Apr. 1, 1965). 15 cents.

Standard stock sizes of machined tool steel bars (flast and squares), SPR267–65 (Aug. 15, 1965). 10 cents.

Publications in Other Journals

This column lists all publications by the NBS staff, as soon after issuance as practical. For completeness, earlier references not previously reported may be included from time to time.

Chemistry

Adhesive bonding of various materials to hard tooth tissues. II. Bonding to dentin promoted by a surface-active comonomer, R. L. Bowen, J. Dental Res. **44**, No. 5, 895–902 (Sept.–Oct. 1965).

Adhesive bonding of various materials to hard tooth tissues. III. Bonding to dentin improved by pretreatment and the use of surface-active comonomer, R. L. Bowen, J. Dental Res. **44**, No. 5, 903–905 (Sept.–Oct. 1965).

Adhesive bonding of various materials to hard tooth tissues. IV. Bonding to dentin, enamel, and fluorapatite improved by the use of a surface-active comonomer, R. L. Bowen, J. Dental Res. **44**, No. 5, 906–911 (Sept.–Oct. 1965).

Approach to simple exponential decay in vibrational relaxation, T. Carrington, J. Chem. Phys. **43**, No. 2, 473–479 (July 15, 1965).

Experimental atomic scattering factors for magnesium oxide, G. Burley, J. Phys. Chem. Solids **26**, 1605–1613 (Apr. 8, 1965).

Major revisions made in new dry cell standard, W. J. Hamer, Mag. Std. **36**, No. 10, 306–308 (Oct. 1965).

Phase equilibria in the system aluminum oxide-tungsten oxide, J. L. Waring, J. Am. Ceram. Soc. **48**, No. 9, 493–494 (Sept. 1965).

Relative signs of nuclear spin couplings in $^1H^{11}B^{19}F_2$, E. B. Whipple, T. H. Brown, T. C. Farrar, and T. D. Coyle, J. Chem. Phys. **43**, No. 5, 1841–1842 (Sept. 1, 1965).

The crystal structure of barium tetraborate, $BaO \cdot 2B_2O_3$, S. Block and A. Perloff, Acta Cryst. **19**, Pt. 3, 297–300 (Sept. 1965).

The system WO_3-B_2O_3, E. M. Levin, J. Am. Ceram. Soc. **48**, No. 9, 491–492 (Sept. 1965).

Vibrational fundamentals of CF_2N_2 from the ultraviolet absorption spectrum, J. D. Simmons, I. R. Bartky, and A. M. Bass, J. Mol. Spectr. **17**, No. 1, 48–49 (July 1965).

Engineering and Instrumentation

A precision noise-comparator, M. G. Arthur, C. M. Allred, and M. K. Cannon, IEEE Trans. Instr. Meas. **IM–13**, No. 4, 301–305 (Dec. 1964).

A variable characteristic impedance coaxial line, J. E. Cruz and R. L. Brooke, IEEE Trans. Micro. Theory Tech. **MTT–13**, No. 4, 477–478 (July 1965).

Impact of new technology on the forest industries, R. W. Smith, Jr., Proc. 2nd Annual Forest Industries Marketing Conference, June 16–17, 1965, pp. 119–130 (University of Oregon Press, Eugene, Oregon, June 16, 1965).

Study of methods for estimating loudness, E. L. R. Corliss and G. E. Winzer, J. Acoust. Soc. Am. **38**, No. 3, 424–428 (Sept. 1965).

Mathematics

Error bounds for asymptotic expansions of special functions in the complex plane, F. W. J. Olver, Proc. Symp. on Error in Digital Computation, U.S. Army Research Center, Madison, Wisconsin, April 26–28, 1965, **Vol. 2**, pp. 55–75 (John Wiley and Sons, Inc., New York, N.Y., 1965).

Metrology

Acoustical thermometer, H. H. Plumb and G. Cataland, Science **150**, No. 3693, 155–161 (Oct. 8, 1965).

An international comparison of inductive voltage divider calibrations at 400 to 1000 Hz, W. C. Sze, A. F. Dunn, and T. L. Zapf, IEEE Trans. Instr. Meas. **IM–14**, No. 3, 124–131 (Sept. 1965).

Precise voltage-ratio measurement, T. L. Zapf, Electro-Technol. **76**, No. 4, 95–102 (Oct. 1965).

Physics

An image source technique for calculating reflection of gamma rays or neutrons, C. Eisenhauer, Health Phys. **11**, 1145–1154 (1965).

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